Hyperloop pod competition

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The **Hyperloop pod competition** is an incentive prize competition sponsored by SpaceX that is being held in 2015–2016 where a number of student and non-student teams are participating to design—and for some, build—a subscale prototype transport vehicle to demonstrate technical feasibility of various aspects of the Hyperloop concept.

There are two judging phases in the 2016 competition: a design competition that was held in January 2016 and an on-track competition to be held later in 2016. The competition is open to participants globally, although all judging will occur in the United States.

A 3D concept sketch of the University of Waterloo *Waterloop* pod taking a test run in the single-tube Hypertube test track. The steel tube is rendered transparent.

30 of the 115 teams that submitted designs in January 2016 have been selected to build hardware to compete on a sponsored Hyperloop test track in mid-2016.[1][2] There were more than 1,000 applicants at earlier stages of the competition.[3]

After the 2016 competition is over, further sponsored competitions are expected.[4]

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History

The outline of the original Hyperloop concept was made public in August 2013 by the release of a preliminary —or alpha level—design document by Elon Musk, with substantial design assistance from an informal group of engineers at both Tesla Motors and SpaceX who worked on the conceptual foundation and modelling of Hyperloop. The preliminary design called for a 2.3–3.4-meter-diameter (90–132 in) steel tube, operating in partial vacuum (nearly airless), utilizing pressurized vehicle "pods" to carry passengers or cargo that would ride on an air cushion driven by linear induction motors and air compressors.[5] The alpha design included a notional route running from the Los Angeles region to the San Francisco Bay Area, paralleling the Interstate 5 corridor for most of its length, so that preliminary economic analysis might be done on the concept.[6] Responses to the design paper release included: "a flash of brilliance" and "hypercool"[7] to "nothing new here"[5] to "hype", "another science-fiction dream," and "completely impractical."[8]

Within days of the 2013 announcement, discussions concluded that building a successful Hyperloop subscale demonstration project could reduce the political impediments while improving cost estimates; Musk suggested that he could choose to become personally involved in building a demonstration prototype of the Hyperloop concept, including funding the development effort.[9][10]

On 15 June 2015, SpaceX announced that they would sponsor a Hyperloop pod design competition, and would build a 1-mile-long (1.6 km) subscale test track near SpaceX's headquarters in Hawthorne, California, for the competitive event. The competition could be held as early as June 2016.[11][12] SpaceX stated in their announcement, "Neither SpaceX nor Elon Musk is affiliated with any Hyperloop companies. While we are not developing a commercial Hyperloop ourselves, we are interested in helping to accelerate development of a functional Hyperloop prototype."[13] More than 700 teams had submitted preliminary applications by July.[14]

Detailed competition rules were released on 29 August 2015, with revisions in October.[15] Formal *Intent to Compete* submissions were due 15 September 2015 and the detailed tube and technical specification—anticipated to be released by SpaceX in October 2015[16]—became available somewhat later.[17] A preliminary design briefing was held in November 2015,[18] and as of October 2015, *Final Design Packages* were due on 13 January 2016. A *Design Weekend* was held at Texas A&M University on 29–30 January 2016 for all invited entrants. The selected pods will compete at the *SpaceX Hyperloop Test Track* in mid 2016.[16]

More than 120 student engineering teams were selected from the preliminary design briefing presentations in November to submit final design packages in January 2016. The designs were released to public view prior to the end of January 2016, and selected teams were invited to build hardware and compete in time trials in mid-2016.[18]

SpaceX announced in January 2016 that they had engaged a Los Angeles-based, Fortune-500, engineering design and construction firm AECOM to build the Hyperloop test track.[19]

At a 29–30 January 2016 meeting at Texas A&M, the designs from the approximately 120 worldwide teams were reviewed and judged. 30 teams were selected to go forward and build prototype Hyperloop pods for the competition later in the year.[1][2]

On 30 January 2016, Musk announced that, due to the level of sophistication of the pod designs as well as design issues with economical design approaches to building the test track, "given this level of enthusiasm, there is no question we are going to have another Hyperloop competition."[4]

Competing teams

Teams advancing to the prototype hardware build stage for 2016 include representatives from four continents and at least six countries. The selected teams include:

- Badgerloop,[20][21] University of Wisconsin-Madison[1]
- Bayou Bengals, Louisiana State University[2]
- bLoop,[22] University of California-Berkeley[1]
- Carnegie Mellon Hyperloop, air-bearing subsystem[23][24] Carnegie-Mellon University[1]
- Codex, pod design uses magnetic levitation suspension; team has only eight members as of February 2016.[25][26][27] Oral Roberts University[1]
- Delft Hyperloop,[28][29][30] Delft University of Technology[1]
- Drexel Hyperloop, building a design with air-bearing suspension and a compression braking using built-up air pressure in the Hypertube. Team is approximately 80 undergraduate students.[31][32] Drexel University[1]
- GatorLoop, pod design uses wheel suspension.[33][34] University of Florida[1]
- HyperLift, St. John's School (Texas) The only high school team in the competition.
- Hyperloop UC, pod design has an air-bearing suspension and compressor like the 2013 Hyperloop alpha design.[35][36] University of Cincinnati[1]
- Hyperloop Toronto,[37] University of Toronto[1]
- Hyperloop at Virginia Tech,[38] Virginia Tech[1]
- HyperXite, University of California Irvine[1]
- Illini Hyperloop, has a history of previous Hyperloop design projects in the Mechanical Science and Engineering program, the first dating to the fall term of 2013. In addition to four subsystem design teams, the Illini group has a fifth, cross-disciplinary team focusing on safety and reliability, the prevention of branching failures.[39] University of Illinois at Urbana-Champaign[2]
- Keio Alpha, Micro-pod architecture consist of active and passive magnetic levitation suspension with a passive eddy current brake. It should weigh less than 45 kg and does not need to carry dummy passenger.[40][41] Keio University[1]
- Lehigh Hyperloop,[42][43] Lehigh University[1]
- Makers UPV Team Valencia, Spain, magnetic levitation based on attraction to the top of the tube. Rail-free and clean tube layout, compensation of inertial forces, reduced air-evacuation cost and up to 30% savings in infrastructure. Powered by detachable batteries, propulsion through compression and expansion of air with a nozzle. Universitat Politècnica de Valencia.[44][45]
- Mercury Three, University of Wisconsin, Milwaukee[2]
- MIT Hyperloop Team, magnetic levitation suspension and high speed are the design focal points. no compressor for this test pod.[46] Massachusetts Institute of Technology[1]
- NYU Hyperloop, *Slate*, a freight-only pod, will use air-bearing suspension; is being designed and built by a team of, as of February 2016, less than ten undergraduate students.[47][48] New York University[2]
- OpenLoop,[49][50] pod design will use an air-bearing suspension and compressor similar to the original

2013 Hyperloop alpha design.[51][52] multi-university team of Cornell University (suspension), Harvey Mudd College (control systems), University of Michigan (fuselage), Northeastern University (suspension), Memorial University of Newfoundland (compressed air), and Princeton University (electrical and cooling)[2]
- Purdue Hyperloop,[53][54] Purdue University[1]
- Team rLoop,[55] the only non-student team that advanced in the competition,[1][56] organized on the social media platform Reddit.[57] With team members from 14+ countries.[58][59]
- RUMD Loop,[60] multi-university team of University of Maryland and Rutgers University[1]
- TAMU Aerospace Hyperloop,[61] Texas A&M[1]
- Team Frigates,[62] Shiv Nadar University, Undergraduate design team consisting of 8 students from different disciplines, namely Mechanical, Physics and Electronics and Communications.
- Team HyperLynx, pod design uses high-speed wheel suspension, with a modular/removable payload design for a pod with a total mass of 140 kilograms (300 lb), aiming for a top speed of 400 kilometers per hour (250 mph).[63][64] University of Colorado-Denver[1]
- UCSB Hyperloop, pod design will use magnetic levitation suspension. Test runs will be accelerated by the Hypertube pusher. Undergraduate design team (senior project) of 20 members.[65] University of California-Santa Barbara[1]
- USC Hyperloop, University of Southern California[2]
- UWashington Hyperloop, University of Washington[1]
- Waterloop,[66] a Canadian team designing a pod with empty mass targeted at 680 kg (1,500 lb) aiming for a cruising velocity of 98 m/s (350 km/h) while carrying a payload of 2,300 kg (5,100 lb).[67] University of Waterloo[1]
- VicHyper,[68] Royal Melbourne Institute of Technology[2]
- WARR Hyperloop, pod design will use an electrodynamic suspension system to levitate and an axial compressor to minimize aerodynamic drag from the residual air inside the tube when the pod is moving at high velocity.[69][*source needs translation*][70] Technical University of Munich[1]

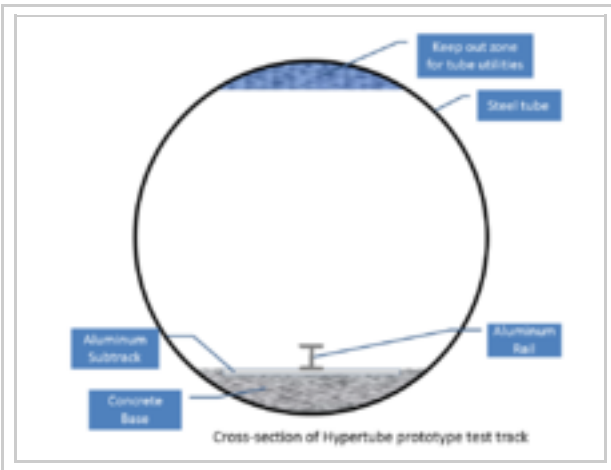
Technical overview

The 2016 competition will take place on a 1-mile-long (1.6 km), 1.8-meter-diameter (6 ft) test track being built in southern California.[11][19] Test pods may not carry any human or animal, and are to be used solely to develop new technologies and subsystems for effecting higher-velocity tube transport systems.[39] The track will facilitate pod test runs where each pod is accelerated, achieves a top measured speed that is reported in real-time, and then decelerates by braking, ostensibly before the end of the test track. There will be a crash pit after the end of the track to absorb the energy of any test pods that fail to come to a stop in the test track tube.[3][4]

Test track

The SpaceX Hyperloop test track—or *Hypertube*[17]—was designed in 2015 and is currently under construction in 2016. The test track itself is also a prototype, where SpaceX anticipates learning from the design, build process and evaluates how to apply automated construction techniques to future Hyperloop tracks.[4]

The design varies significantly from the Hyperloop tube design shown in the initial alpha-level Hyperloop design document released in 2013.[6] The Hypertube test track is designed to enable competitors who implement a wide array of designs and build pods that will test a variety of subsystem technologies that are important to new vehicle transport systems. This will include Hyperloop-specific pods—with air-bearing suspension and low-pressure compressor designs—as well as wheeled vehicle and magnetic levitation rail designs that will support a wide array of vehicle technologies to be tested. Some pods are expected to test only particular subsystems rather than a full Hyperloop-capable pod vehicle design; as well, many pods will have no on-pod compressor to prevent the high-speed choked-flow problem, very unlike the Hyperloop alpha design.[17]



Cross section of the *Hypertube* test track under construction for the Hyperloop pod competition in August 2016.

Multiple systems will be allowed for propulsion and for levitation/suspension of various team pods. Three explicit suspension types are called out: wheels, air bearings, and magnetic levitation. Pod propulsion may be *On-pod*—as envisioned in the alpha Hyperloop design—or for the Hypertube test track, may use a SpaceX-provided *Pusher* to accelerate pods up to speed in the first 15 percent of track length, or even be unique (team-specific) *Off-pod* propulsion systems that would need to be integrated into the Hypertube for that Pod's specific test run.[17]

Specifications

The test track specifications as of January 2016 include:[17]

- Outer diameter: 1.83 meters (72.0 in)[17] (vs. approximately 2.3–3.4 m (90–132 in) for the tube in the initial alpha Hyperloop design document)[6]
- Inner diameter: 1.79 meters (70.6 in)
- Wall thickness: 18 millimeters (0.70 in)[17] (vs. 20–25 mm (0.80–1.0 in) for the tube in the initial alpha Hyperloop design)[6]
- Length: 1.6 kilometers (1 mi) (approximate)
- Materials
  - Tube: ASTM A1018 Grade 36 carbon steel
  - Rail: Aluminum 6061-T6
  - Subtrack: AA1370-50[71] Aluminum alloy for electrical applications
  - 1.2 m-wide (48.0 in) Concrete base inside the tube to support wheeled-vehicle pods
- Subtrack thickness: 25 millimeters (1.0 in) for first and last 61 meters (200 ft); 13 millimeters (0.5 in) for remainder of tube
- Internal pressure: 0.14–100 kilopascals (0.02–14.7 psi) (competitors may select tube operating pressure "in order to support various types of propulsion systems, compressors (if applicable), and outer mold lines"
- Pumpdown time is expected to be as long as 30 minutes to reach the minimum pressure rating.
- Thermal control system: none provided in the Hypertube. Tube temperature is expected to vary based on time of day and weather, and competitors will need to design their pods accordingly, mitigating thermal hotspots during pumpdown and test runs.
- Braking system: the only Hypertube-provided braking is the emergency foam pit at the end of the mile-long tube. Pods are expected to provide their own pod-specific braking system, one that will react force to

the Hypertube by one of four methods: either against the steel tube, or concrete base, or aluminum subtrack, or central rail. Tube requirements limit friction braking against the subtrack or rail to specified limits.
- Power: none provided on the test track during testing; $240V_{AC}$/50A and $120V_{AC}$/15A power provided in the pod waiting area up through the pre-launch phase within the tube
- Communications: SpaceX will provide a standard Network Access Panel (NAP) device (approximately 250 mm × 200 mm × 38 mm (10 in × 8 in × 1.5 in)) for mounting on each pod which will communicate to the in-tube network via two, redundant, 1–25 GHz, wave blade antennas. The NAP will also record temperature, acceleration, vibration and shock of each pod in real time during each test run.
- Navigation aids: The tube will include a series of circumferential reflective stripes applied to the inner circumference of the tube, located on the top of the tube, to be used for optical pod navigation, and in particular, awareness of the last 300 meters (1,000 ft) of the tube so pod braking may be safely effected.

Vehicle pods

Three different variations of exterior design of the vehicle pods for the Hyperloop are being explored. One Pod design uses Magnetic levitation; this design was used by the winner of the “Best Overall Design Award” MIT.[72] The other major design variation is the Air bearing design. This design relies on a system to create a bed of air for the Pod to glide on and is the basis of Elon Musk’s original Hyperloop idea.[6] The third design is use by University of Colorado, Denver's Hyperlynx team. Their design utilizes high speed wheels for speed under 100 Miles Per Hour and air bearings for higher speeds.[63][64]

The inside design of the pods vary by team. Some of the teams are solely building pods designed for cargo transport. Other teams designed pods to transport passengers, while other designs would allow adjustments to be made to the pod to allow both, while MIT's team's initial design did not have room for a passenger or cargo and solely relied on the engineering of the pod.[73] The University of Colorado, Denver's team incorporated a removable capsule that allows it to be exchanged for a cargo hold or passenger space.[63][64] New York University's team has created a vehicle that only allows cargo transportation.[47]

Competition results

Phase 1: Design weekend (January 2016)

Five design awards were assigned following the January design weekend.[1]

MIT Hyperloop Team's design was awarded received the "Best Overall Design Award",[1] among the 23 designs selected to move to the prototype stage. The design proposes a 250 kg (551 lb) pod with a carbon fiber and polycarbonate sheet exterior. It is elevated by a passive magnetic levitation system comprising 20 neodymium magnets that will maintain a 15 mm (0.6 in) distance above the track.[72] The team says with air pressure at 140 Pascals, the pod could accelerate at 2.4 G and have 2 Newton aerodynamic drag when traveling at 110 m/s. The design includes a fail-safe braking system that automatically halts the pod should the actuators or computers fail, and low speed emergency drive wheels that can move the pod 1 m/s.[72]

Delft Hyperloop received a "Pod Innovation Award",[1] while *Badgerloop*, *Hyperloop at Virginia Tech*, and *HyperXite* at UC Irvine each received a "Pod Technical Excellence Award".[1]

In addition to the five pod awards above, nine subsystem awards and three "design only" awards were given to teams, most to teams that were not chosen to continue on to the on-track competition. Technical awards for outstanding technical merit in subsystem and design, based on "innovation and uniqueness of subsystem design, full Hyperloop system applicability and economics; level of design detail; strength of supporting analysis and tests; and quality of documentation and presentation." [74]

Best Overall Subsystem Award: Auburn University Hyperloop Team,[75] Auburn University; Special Innovation Award in the Other Subsystem: RIT Imaging, Rochester Institute of Technology; :Levitation Subsystem Technical Excellence Award: TAMU Aerospace Hyperloop, Texas A&M; Braking Subsystem Technical Excellence Award: VicHyper, RMIT University; Propulsion/Compression Subsystem Technical Excellence Award: Makers UPV Team (http://hyperloopupv.com/), Universitat Politècnica de València; Safety Subsystem Technical Excellence Award: UWashington Hyperloop, University of Washington (linked above); Subsystem Technical Excellence Awards: Hyped,[76] University of Edinburgh; Conant Hyperloop Club, Conant High School;[77] Subsystem Innovation Award: Ryerson's International Hyperloop Team, Ryerson University.[74] Top Design Concept Award: Makers UPV Team (http://hyperloopupv.com/) (see above); Design Concept Innovation Award: Nova Hyperloop Team, University of Cairo; Design Concept Innovation Award: Auburn University Hyperloop Team (see above).[74]

Phase 2: Test track runs (mid 2016)

Competitive runs in the Hypertube test track will be awarded based on various classes (fully functional pod, susbsystem test pod, etc.) and pod mass. Detailed criteria will be released later in 2016.

Phase 2 is anticipated to be in August 2016, but there remains some flexibility in the dates. If the track is completed earlier, test runs may begin earlier as well.[78]

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